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OBSERVATIONS ON A MIGRATION OF *PIERIS BRASSICAE* L. AT SKOKHOLM ISLAND, PEMBROKESHIRE, IN AUGUST, 1947.

By P. J. Conder.

(*Dale Fort Field Centre, Haverfordwest.*)

A movement of butterflies, mostly *Pieris brassicae* L., in a westerly direction out to sea, had been observed in the district as early as 9th August, 1947, when they were reported moving westwards at Grassholm Island, eleven miles from the Pembrokeshire coast. On the following day a movement was observed at Skokholm Island.

On the 21st August it was decided to keep a concentrated watch on Skokholm, in order to arrive at some idea of the number of butterflies involved. The first of a group of eight observers began watch at 09.00 hours G.M.T. (10.00 hrs. B.S.T.) at the intersection of two walls which gave a north-south and an east-west base line. The numbers of all species of butterflies seen were counted as they moved across a front of 100 yards, and the direction noted to the eight main points of the compass. Observations ceased at 12.00 G.M.T., and were recommenced at 13.00 hours. At 15.10 hours a large movement of *Pieris brassicae* commenced, and the observers found it necessary to shorten the front to 20 yards and to concentrate only on that species. Observations ceased at 17.00 hours G.M.T.

It should be noted that since Skokholm is in approximately 5° W. longitude, Greenwich Mean Time is about 20 minutes ahead of local sun-time, which is the only natural time, so the observations really started at 08.40 sun-time.

The weather during the previous three weeks had been very sunny and warm and no rain had fallen since the 25th July. August 21st was sunny with a slight haze, and with a maximum shade temperature of 72° F.

Table I shows the wind direction and force as recorded at four stations within a radius of four miles. The wind was constantly from the easterly quarter and steady in direction at three of the stations, but a little more variable at the point of observation. Skokholm Lighthouse, R.N.A.S. Dale, and St. Anne's Head Coastguard stations are each in exposed positions, but the Bird Observatory is more sheltered, and it is possible that the topography of the island may have locally disturbed the direction and course of the wind.

Four species of butterflies were observed—*Pieris brassicae, Vanessa atalanta, Pyrameis cardui* and *Colias croceus*—and fig. 1 shows the total number of each observed in each hour going to each of the eight points of the compass. Between 09.00 and 11.00 hours the movement was small, with little directional tendency. *C. croceus* was only present in small numbers, and between 10.00 and 14.00 hours was moving in an easterly direction, but after this tended to straggle. *V. atalanta* was recorded most frequently between 09.00 and 11.00 hours, but throughout the period were chiefly flying to the east. *P. cardui* was less common than *V. atalanta* and was only seen between 09.00 and 11.00 hours, when most were flying to the east or north-east.

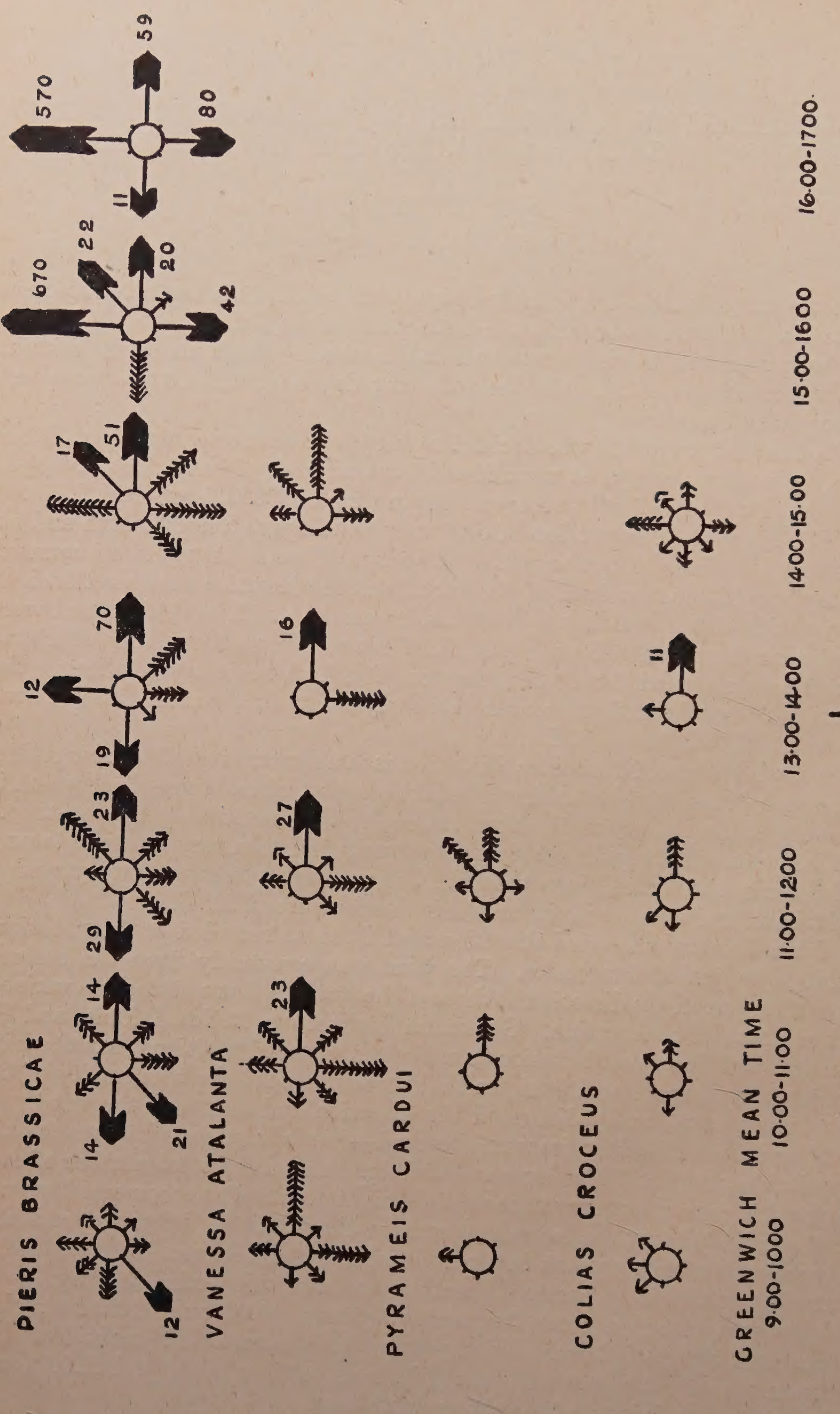

Fig. 1.—Hourly totals of the four species of butterflies showing numbers and direction of movement.

TABLE 1.—*Wind strength and direction at four stations; the greatest distance between any two is four miles.*

	Skokholm Bird Obs. (100 feet).	Skokholm Lighthouse (150 feet).	R.N.A.S. Dale (200 feet).	St. Anne's Head Coastguards (150 feet).
09.00 hrs.	N.E. 3	—	E.N.E. 4	—
10.00 ,,	S.E. 2	E.N.E. 3	E'N. 4	N.E. 7
11.00 ,,	—	—	E'N. 4	—
12.00 ,,	—	—	E. 4.	—
13.00 ,,	—	—	E'N. 4	—
14.00 ,,	E.N.E. 2	E.N.E. 2	E'S. 4	E. 4
15.00 ,,	N.E. 2	—	E'N. 4	—
16.00 ,,	—	—	E. 4	—
17.00 ,,	—	E.N.E. 2	E. 4	E. 2

Between 09.00 and 11.00 hours the movement of *Pieris brassicae* was small and the general direction was south-west, but between 11.00 and 12.00 rather more were recorded moving to the east than to the west. Between 13.00 and 14.50 hours this difference was maintained.

At about 15.00 the main movement began and the numbers increased from about 30 butterflies crossing a 100-yard front from 14.50–15.00 to over 150 over a 20-yard front between 15.20 and 15.30; this latter is equivalent to 750 on a 100-yard front or an increase of about 22 times the previous number.

The direction of the movement changed to the *north* between 15.10 and 15.19 hours.

The first wave passed between 15.20 and 16.00 hours with a peak of about 300 butterflies on a 20-yard front in 10 minutes between 15.30 and 15.40. There was a second smaller peak of 125 butterflies between 16.30 and 16.40 (see fig. 2). Unfortunately, regular observation ceased at 17.00, but the movement continued and 81 were observed passing to the north between 16.50 and 17.00 hours.

Fig. 2 shows the percentage of *P. brassicae* observed flying in an easterly, southerly and westerly direction during and just before the main flight to the north. Between 15.00 and 15.10, before the rush began, 76 per cent. were flying in those directions; but as the total numbers increased the percentage decreased, so that during the peak of the wave only 2 per cent. were recorded as not moving in the main direction. When the rush passed the percentage increased slightly, and then remained fairly constant. Although the percentage decreased the actual numbers flying in all directions increased.

Throughout the whole day the wind was from the easterly quarter, but the preponderating direction of movement for *P. brassicae* during the morning was towards the west and south-west, i.e. with the wind; in the early afternoon it was towards the east into the wind; and during the main flight to the north across the wind. Thus the observations support the idea that the direction of the wind is not the determining factor in the direction of the movement.

Table 2 shows the average height at which *P. brassicae* flew until the main rush began, after which the observers were unable to record both height and

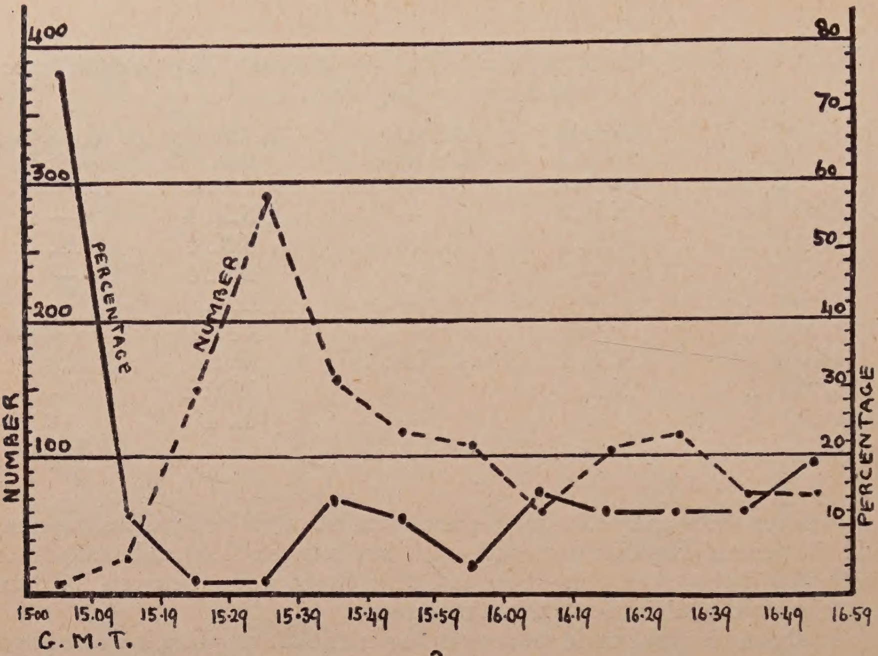

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Fig. 2.—Ten minute totals of *P. brassicae* from 15.09–16.59, showing percentage travelling opposite to the main movements.

numbers. It can be seen that there is a tendency for the height to decrease throughout the day, and to be slightly greater when the butterflies were flying down wind. During the rush the butterflies flew from 1–10 feet above the ground and mostly at about 2 feet.

Table 2.—*Average height in feet above the ground of* P. brassicae *flying in different directions at different times of the day.*

	09.00–10.00 hrs.	10–11.00 hrs.	11–12.00 hrs.	13–14.00 hrs.	14–15.00 hrs.	15–16.00 hrs.
N.	3·5	—	3	2	2	1·5
N.E.	—	3.5	2	—	1·6	2
E.	2	2.4	1·6	2·1	1·9	2
S.E.	—	2.6	1·6	2·5	2	2
S.	4	3·6	3	2·2	2	—
S.W.	6·6	6	3·4	3	2	—
W.	4·5	6·5	8	4·1	2·4	2
N.W.	3	4	—	—	—	—

Acknowledgment.

I am very grateful to Dr. C. B. Williams for his assistance in writing this paper.

NOTES ON THE MORPHOLOGY OF SOME SPECIES OF TANYPODINAE (DIPTERA CHIRONOMIDAE).

By Mrs. M. Joan Morgan, M.Sc., F.R.E.S.

Although the early stages of the Chironomidae have received some study, there are still many species of which the larvae are unknown.

Many larvae and pupae have not been correlated with the final instar, and the complete life histories of very few species have been described in detail.

During investigations of the life histories of several species, attempts were made to distinguish between immature stages so that these could be identified without waiting for the imago to emerge. Descriptions of groups of larvae and pupae by Zavrel (1916) are largely incorporated in Goetghebuer (1927), but many species remain undifferentiated within the groups.

All specimens described below have been reared from the egg or larval stage and the imagines identified. The classification used by F. W. Edwards (1929) has been followed throughout.

The different groups of larvae are not easily distinguished except by examination of the mouth parts under the microscope. In the pupal phase the genus, if not species, can readily be recognized on inspection of the respiratory trumpet and anal segment. The exuviae of both larvae and pupae are of more value for identification than the living insect. Pupae may be sexed by the shape of the genital sheath of the last abdominal segment. In the male this is much larger (fig. 3).

Though collections were made at all seasons in very varied habitats during the course of the last 5½ years no specimens of *Clinotanypus* have been found.

Anatopynia nebulosa (Meigen, 1804).

Larva.—10·5 mm., occasionally as long as 12 mm. The dorsal papilla of fully grown larva bears 12 hairs, the longest being three times the length of the papilla. Anal papilla scarcely a third of the length of the posterior prolegs.

Pupa.—Lobes of last abdominal segment (fig. 1) have a straight inner edge ending in a sharp point. Respiratory trumpet has large sieve plate (fig. 5) roughly in the shape of an isosceles triangle. Female pupae tend to be somewhat longer.

Average length of male exuviae : 8 mm. (16 specimens).

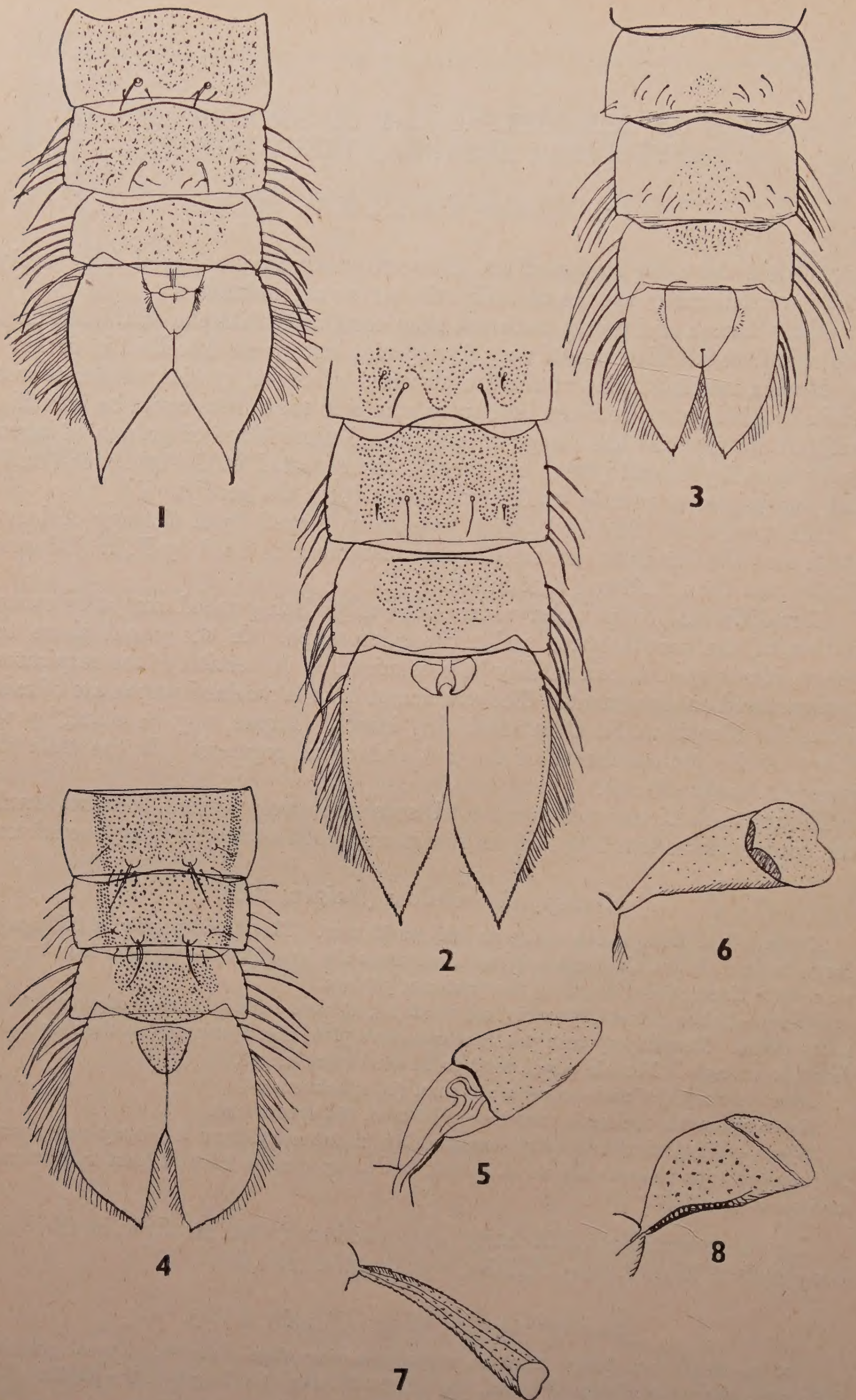
Average length of female exuviae : 8·75 mm. (14 specimens).

Imago.—Wing markings vary considerably in intensity from a clearly recognizable *A. nebulosa* type to one close to *A. notata*, but all specimens have at least indications of two spots in cell R5.

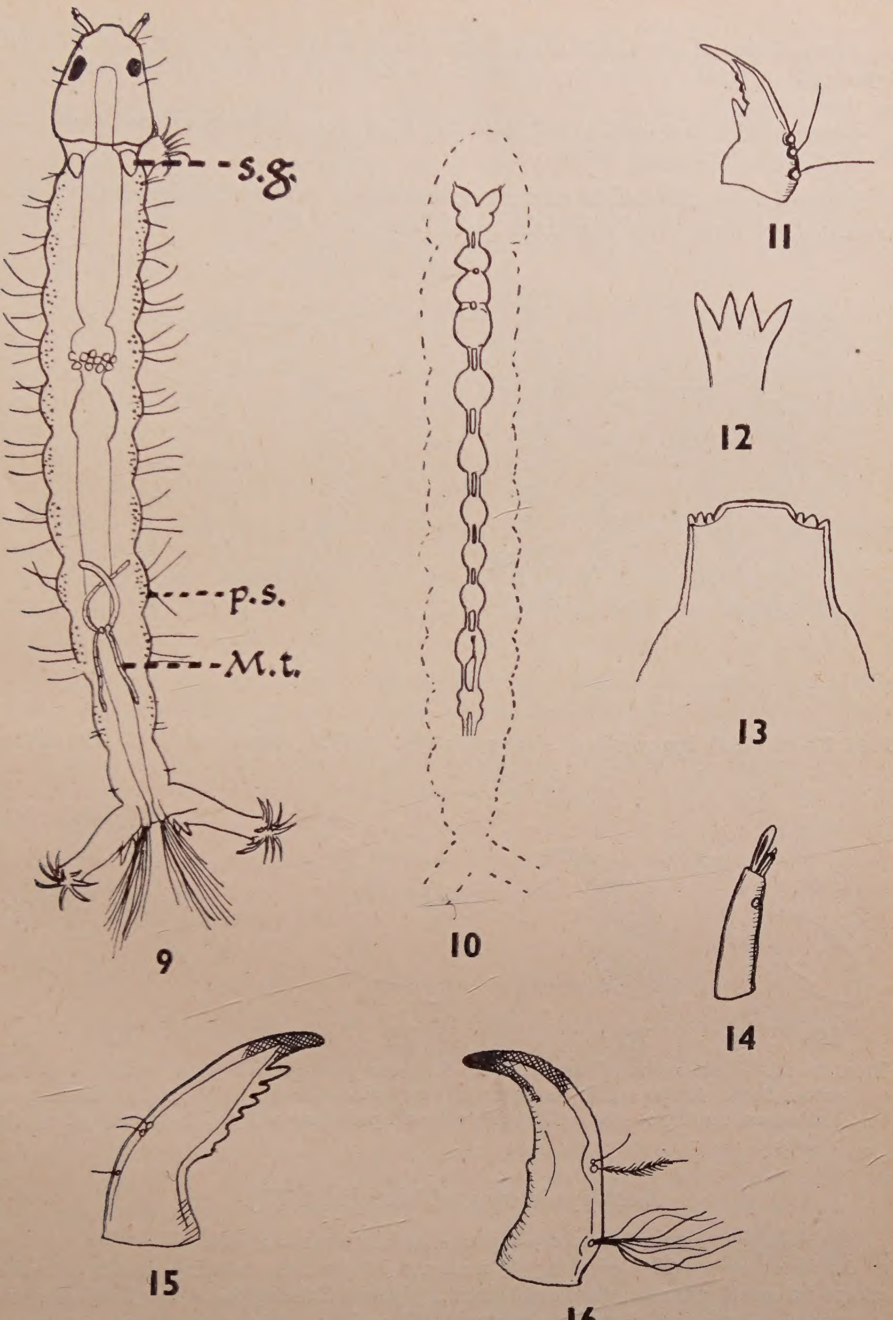
Larvae were collected in fairly large numbers in ten localities in the neighbourhood of Wray Castle, Halifax, and Douglas (I.O.M.).

Anatopynia goetghebueri (Kieffer, 1918).

Larva.—9–10 mm. long ; that is, slightly smaller than *nebulosa*. Dorsal papilla of full grown larva bears 10 or 11 hairs, the longest 2½ times the length of the papilla. Anal papilla about half the length of the posterior prolegs.



Figs. 1–8.—Pupae of *Anatopynia* spp. (1) End of abdomen of *A. nebulosa*; (2) of *A. Goetghebueri*; (3) of *A. varius*; (4) of *A. trifascipennis.* (5) Respiratory trumpet of *A. nebulosa*; (6) of *A. goetghebueri*; (7) of *A. varius*; (8) of *A. trifascipennis.*

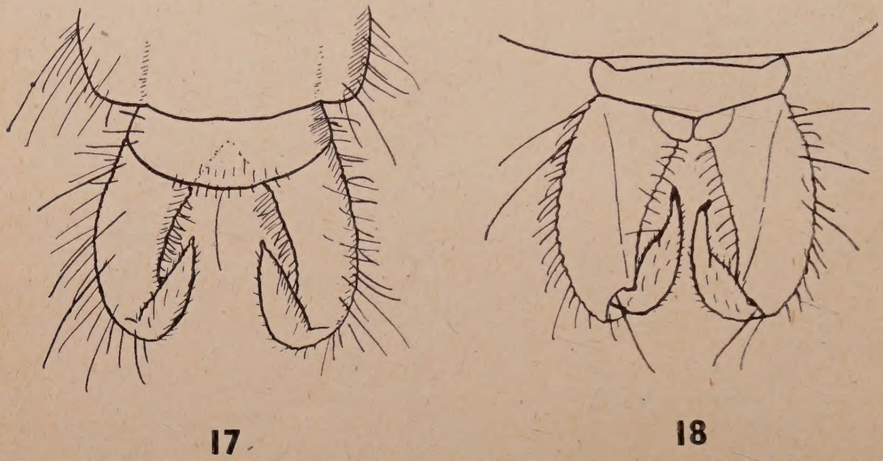


FIGS. 9–16.—Larvae of *Anatopynia* spp. (9–14) First instar larva of *A. varius.* (9) Dorsal view, × 100; (10) central nervous system, × 100; (11) left mandible, × 600; (12) labial plate, × 1000; (13) labial process, × 1000; (14) right antenna, × 550. (15) Right mandible of full-grown larva of *A. varius*, × 300. (16) Left mandible of same of *A. trifascipennis*, × 300; *s.g.*, salivary gland; *M.t.*, Malpighian tubule; *p.s.*, light brown pigment spots.

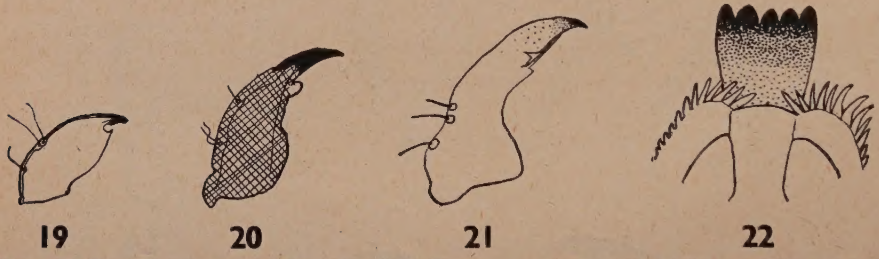
Pupa.—Lobes of last abdominal segment (fig. 2) have a convex inner edge gradually tapering to a point. Respiratory trumpet has kidney-shaped sieve plate smaller than *nebulosa* (fig. 6).

Imago.—Shape of style of hypopygium (fig. 17) differs reliably from *nebulosa* (fig. 18). Body appears slighter than *nebulosa.*

Larvae were collected in moderate numbers in seven localities in the neighbourhood of Wray Castle, Halifax, and Douglas (I.O.M.).



FIGS. 17–18.—Male hypopygia of *Anatopynia* spp. (17) *A. goetghebueri*; (18) *A. nebulosa.*



FIGS. 19–22.—Mouthparts of larvae. (19) *Tanypus punctipennis*, right mandible of full-grown larva, × 300; (20) the same of *Procladius choreus*, × 300; (21) the same of *Pentaneura nubila*, × 470; (22) horse shoe-shaped plate of hypopharynx of *P. nubila*, × 500.

Anatopynia varius (Fabricius, 1787).

Egg mass 5 × 7 mm., horseshoe-shaped, eggs in rows in the jelly.

1st instar larva.—The larva (fig. 9) measures 1·3 mm. on hatching, and is colourless except for small granules of yellowish brown pigment laterally in all the body segments except the last two. Abdominal segments I–VII each bear 3 long hairs laterally, as compared with the larger number in later instars; segment VIII has 2 small hairs, and segment IX has one. The thoracic segments each bear 2 hairs on either side. The dorsal papilla bears 10 hairs. The teeth of the mandible and labial plate are large in proportion as compared with those of later instars. The mandible (fig. 11) has one large lateral tooth and the others are much smaller; on its outer edge it bears 3 hairs as in the final larval instars.

The labial process (fig. 13) is markedly different in shape. The antenna is proportionately wider than in later instars and the terminal segments are shorter than the lobed process (fig. 14).

The nervous system (fig. 10) is conspicuously large as compared with the size of the body. The eyes are conspicuous and are much larger in proportion than in later instars. The distance between them is ·076–·08 mm. and seems to be constant in this instar.

Full grown larva.—8–9·5 mm. but size appears to vary with habitat. Both Goetghebuer (1927) and Zavrel (1916) give length as 10–11 mm. and Stuart (1941) gives 12–14 mm. Body dorso-ventrally flattened and narrows rather suddenly posteriorly. Dorsal papilla bears 20–30 hairs (Goetghebuer gives 18–20).

In some structural details my specimens differ in several respects from those described by T. A. Stuart (1941) from sea shore pools. Stuart's diagram of the mandible shows two teeth and no lateral hairs. I find six or seven teeth, the proximal ones being smaller (fig. 15) and three lateral hairs are always present. The antennae differ chiefly in the size and relative proportions of the apical portion and the appendage of the basal joint. Stuart gives six or seven hairs on the dorsal papilla in the diagnosis of the species (*cf.* 20–30) though later on he states that after the first instar there are " at least 12." Again, he says " these larvae are definitely predaceous and carnivorous and will not survive unless animal food is present." My specimens eat plant material fairly readily if animal food is not abundant. My figure of the mandible coincides with that of Lenz in Lindner (1936) and other characteristics agree.

Pupa.—Anal lobes (fig. 3) somewhat similar to *A. goetghebueri* in shape, but median border bears hairs instead of teeth. Respiratory trumpet (fig. 7) long and narrow, dilated trachea ending in a heart-shaped sieve plate.

Imago.—Considerable variation in intensity of colour and amount of shading in wings, though basic pattern is always recognizable and the species can be distinguished on this characteristic alone.

Larvae were collected in fairly large numbers in eleven localities in Liverpool, Wirral, Wray Castle, Halifax, Isle of Man; and swarms of adults in Halifax (Sept. and Oct.).

Anatopynia trifascipennis (Zetterstedt, 1838).

No larvae or imagines collected, but a pupa from the surface of Lake Windermere bore the larval exuviae attached to the tip of its abdomen.

Larval exuviae.—Exuviae whitish, with a dark brown head capsule, the latter colour differing from all other species examined. The claws of the posterior prolegs are pale yellow. The mouth parts are all fairly strongly sclerotised. The mandible (fig. 16) has a large terminal tooth, and as far as I could see on this specimen there appeared to be only one lateral tooth. As in *A. varius* there are three hairs on the lateral border, two close together in the middle and one near the base. They differ strikingly from those of *varius* (fig. 15), and if this is a representative specimen the larva could be identified on this character alone. *A. varius* has three short simple hairs, while in *trifascipennis* the most distal one is simple, though long, the next is longer and pinnately branched, while the proximal one bears, near its base, a tuft of at least eight branches, twice the width of the mandible in length. As far as I am aware this has not been described before. Zavrel figures the mandible without the hairs and dismisses it as " similar to *Macropelopia*." Though the antennae of the two species are approximately the same length, in *trifascipennis* the distal segments and appendages are much smaller, and constitute only one-eighth of the total length as compared with one-third in *varius*. The paralabial combs differ in shape and *trifascipennis* has only five large teeth, while there are seven in *varius*. The maxillary palp of *varius* shows a curvature, but there seems to be no other important difference. Unfortunately, it was impossible to see the labial plate in this specimen of *trifascipennis*.

Pupa.—Respiratory trumpet (fig. 8) much wider than *varius* and sieve plate three times as wide. Lobes of anal segment larger and slightly wider than other abdominal segments (fig. 4). Curved hairs on dorsal surface of abdominal segments are larger and stronger than in *varius*.

Tanypus punctipennis (Meigen, 1803).

Larva.—Length of full-grown larva 6–7 mm.; Zavrel gives 11 mm. for his specimens. Mandibles (fig. 19) stand out well in front of head and are wider and less heavily sclerotised than in other species studied. Paralabial combs have seven rounded teeth and are joined by a narrow bridge ventral to the labial plate.

Pupa.—Exuviae quite colourless except for respiratory trumpets which appear conspicuously black. All abdominal segments with lateral fringe of long hairs. Distinguished readily from pupae of other genera by these features and by small anal lobes.

Larvae were found in small numbers at Calderstones, Liverpool.

Procladius choreus (Meigen, 1804).

Full grown larva.—Length varies locally, and there may be some correlation between size and type of habitat; Lake Windermere specimens (9·5 mm.) in clear lake water; Isle of Man specimens (7–8·5 mm.) in shallow pool overhung by trees; Halifax specimens (6 mm.) in puddle partly filled with rubbish. Zavrel gives length as 9 mm. It seems likely that unfavourable conditions would restrict growth.

Form of the mandible (fig. 20) is characteristic of genus *Procladius*. It terminates in a large heavily sclerotized pointed tooth and bears three bristles laterally; the lateral tooth is rounded and pale in colour.

Imago.—Variation in intensity of wing shading and in colour of thorax and abdomen in different specimens make it difficult to identify this species satisfactorily. The shape of the hypopygium (Goetghebuer (1927)) is the most useful distinguishing character.

Larvae collected in six habitats, in Lake Windermere, Halifax area and in the Isle of Man.

Pentaneura monilis (Linnaeus, 1763).

One of the commonest species of the genus *Pentaneura*, the immature stages of *P. monilis* are fully described by Goetghebuer. None of my adult specimens exactly corresponds to the wing diagram in Goetghebuer and Lenz (1936) and it is possible that there is a certain difference in British specimens, as wing marking varies both in intensity and distribution of shading.

Larvae collected in small numbers in 15 localities, 13 in the neighbourhood of Wray Castle, the others in Liverpool and the Isle of Man.

Pentaneura nubila (Meigen).

Larva.—6–7 mm. when fully grown; light brown with darker markings dorsally. Three or four short lateral hairs on each segment. Anal papillae long and narrow and half the length of posterior prolegs. Dorsal papilla with about 7 hairs, five times longer than length of papilla. Has typical mouth parts of *nigropunctatus* group of Zavrel. Mandible (fig. 21) differs slightly from other species. Horse shoe-shaped plate of hypopharynx has 12 teeth (fig. 22).

Pupa.—Dark orange-brown with ends of wing covers pale grey-brown. Length: width of respiratory trumpet = 4 : 1, 10–12 teeth at its base. Two long glandular hairs in middle of lateral edge of anal segment.

Imago.—Recognized at once by the two transverse bands on the wings, but occasionally these are very pale and not easily seen.

Larvae collected in three habitats in neighbourhood of Wray Castle and once in Douglas, I.O.M.

ACKNOWLEDGMENTS.

Mr. P. Freeman and Mr. R. L. Coe of the British Museum (Natural History) have kindly checked my identifications of the imagines of all species I have studied, and find them correct.

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BOOK NOTICE.

Good Control of Insect Pests. By S. G. JARY. Sm. 8vo. London (English Universities Press, Ltd.), 1948. Pp. xi + 13–216, text illust. Price 4s. 6d.

This volume is one of the *Teach Yourself Farming* series. The more important pests of garden and farm crops are dealt with in such a way as to provide information likely to prove useful to the general reader as well as to the farmer and student.

The introductory chapter describes the scope of the work, and succeeding chapters deal with Insects and their Relations, Insecticides—Nature and Properties, Insecticides—Preparation and Use, Pests of Agricultural Crops, Pests of Fruit and Hops and Pests of Garden, Market Garden and Glasshouse Crops.

In the final chapter the wider outlook on pest control by direct and indirect methods is discussed.

THE NYMPH OF *ISCHNURA PUMILIO* CHARPENTIER (ORDER ODONATA).

By Lt.-Col. F. C. **Fraser**, I.M.S. (Retd.), F.R.E.S.

The nymphs of all the British Odonata have now been described save that of *Ischnura pumilio* Charpentier, although not all have been described from British material. It is true that Roster, in 1886, described what purported to be the nymph of *pumilio*, but the description bristles with so many inaccuracies that it is extremely doubtful if he had the correct nymph before him. Lucas, in his *Monograph on the Aquatic Stages of the British Odonata*, having no knowledge of the nymph of this species, was compelled to fall back upon Roster's description, but he comments on the gross improbabilities of the measurements therein given. Personally I hold the opinion that either Roster's nymph was not that of *pumilio* or that he made his description from a shrunken and distorted exuvium.

On the 3rd July, 1947, I secured locally two females of *pumilio*, these being collected from a very large and flourishing colony. They were placed under a glass cover in which I had put an enamel pie-dish filled with water and a few floating leaves of *Nuphar luteum* Sm. Although I was not very sanguine, I hoped that I might persuade them to oviposit. One female was very restless, so I removed it as it was disturbing the other; the latter remained passive, sitting quietly on the side of the dish, with its abdomen overhanging the water. I gently pushed one of the floating leaves beneath it and titulated the end of her abdomen with the point of a pencil. This slight stimulus had instant success, for the insect at once commenced to palpate the surface of the leaf with her ovipositor and presently, curving the abdomen strongly so as to bring the end segments perpendicular, thrust her ovipositor forcibly into the leaf. This was accomplished with a boring motion, the abdomen being wriggled from side to side in the effort put forth, very much as one would employ an awl. An egg being deposited in the boring, the ovipositor was slowly and deliberately withdrawn, apparently to allow the egg to be secured by the tissues closing in upon it. The point of the ovipositor was now shifted slightly anterior to the first puncture and a second egg deposited in the same manner as the first, and this was repeated until some 5 to 7 eggs had been inserted. Another row was then started parallel to the first, and so on until a decided dark patch was observable, caused by the numerous crowded punctures. I watched the insect at work for some two hours at intervals, during which no less than 76 punctures were counted, after which the insect ceased and appeared to be exhausted.

The actual date of hatching was not observed unfortunately, but the first tiny nymphs were noticed on 30th July, being then from 2·5 to 3·0 mm. in length, including the caudal gills. On 8th August a number were examined under the microscope and found to be of variable sizes—1·5, 2·0, 5·0 and even one as large as 8·5 mm.—so that it was evident that hatching took place at widely variable periods or else the first comers lived and thrived on the following ones, which is, I fear, the probable explanation of these anomalies in size. The young nymph (fig. 1) is all head, legs and caudal gills, the trunk being quite out of proportion to its appendages. The antennae, which consist of only 6 segments at this age, are proportionately very much larger than in the full adult (fig. 1) and each segment has several trichiae springing from its apex or middle. The long, slender legs, which in the full adult are naked, are now armed with long setae, the anterior femora with 3 of such on its extensor surface; the tibiae with numerous spines, the anterior ones, even at this early date, being furnished with an apical comb, which serves to emphasize the importance of cleanliness to these insects and probably to prevent the mouth parts becoming clogged with diatomaceous material, volucellae and other infusoria which form the usual lodgers of all Odonate nymphs. The caudal gills are quite unlike the lamellated structures of the full adult, being long tapering spine-like organs furnished with long trichiae. The tracheal system

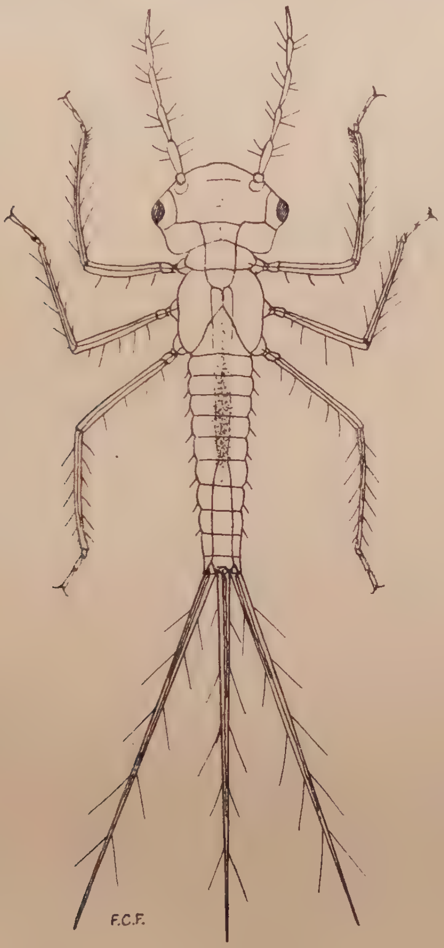

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Fig. 1.—Young nymph of *Ischnura pumilio* Charpentier at the age of five weeks.

and other details of the internal anatomy are clearly discernible in the translucent nymph.

Nymphs examined on 10th December, 1947, were found to have developed partially lamellated caudal gills, which were beginning to assume a lanceolate shape, but were still very narrow; the trichiae had increased in number to about 12 to 14 and were now so short that a better appellation would be setae. The main tracheae bifurcated at the base of segment 10, the two inner branches going to the dorsal or medial gill; the outer branch again bifurcated at the apex of segment 10 and the two branches thus formed passed on into the lateral gills on each side. The nymph was now beginning to show decided dark markings, the pigmented rings on the femora and tibiae being especially well defined whilst the abdomen showed two interrupted longitudinal dark bands. The head was proportionately smaller and some setae were present on the outer side of the occiput. The spines on the legs were more numerous, but very much smaller and inconspicuous. There was as yet no sign of the wing sheaths.

THE FULL ADULT NYMPH.

From March, 1948, onwards, growth of the nymphs was very rapid and by the end of April it was evident from the fully fashioned caudal gills and the length of the wing-pads that they had undergone their last moult. A number of the largest specimens were segregated in glass jars as gross cannibalism was going on and these were fed apart. The first nymph left the water and the imago emerged on 20th May, a male, which did not attain its full colouring until a period of some five or six days. A female followed on 2nd June, but previous to this, final measurements, notes and figures were made of the adult nymphs. From oviposition to emergence of the imago had taken 324 and 337 days respectively, and somewhat longer in the case of others which emerged during the month of June.

The adult nymph from head to apex of caudal gill measures 21 mm., the caudal gills making up slightly more than 5·0 mm. of this. The exuviae were found to measure only about 16 mm. in length, indicating that considerable shrinkage occurs after emergence, due partly to telescoping of the abdomen and partly to distortion of the gills. The antennae have 7 segments, the scape being the longest segment; the latter has its base and apex ringed with black, whilst the other segments have the apex only darkened. The head is broader than deep and roughly trapezoidal in outline, although the face is advanced; it, as well as the legs and gills, are now more in proportion to the rest of the body; the ocelli are distinct as pale unpigmented spots on the vertex; some 5 to 7 small spines are found on the outer and posterior part of the occiput, behind the eyes. The eyes, in some, have two narrow, pigmented, equatorial and subequatorial bands circumventing them, but these are usually absent and are probably only a manifestation of the approaching emergence of the imago. The wing-pads are depressed, but still somewhat cylindrical or sausage-shaped, their apices extending well on to the 4th abdominal segment. The legs, which are now naked and devoid of spines save for some minute setae on the femora, are long and slender, the hind femora extending to the level of the apices of the wing-pads; each femur has a medial and an apical dark pigmented annule, and a similar ring is found on the tibiae near the proximal end. The anterior tibiae have a well developed comb at the distal end, which has hardly changed

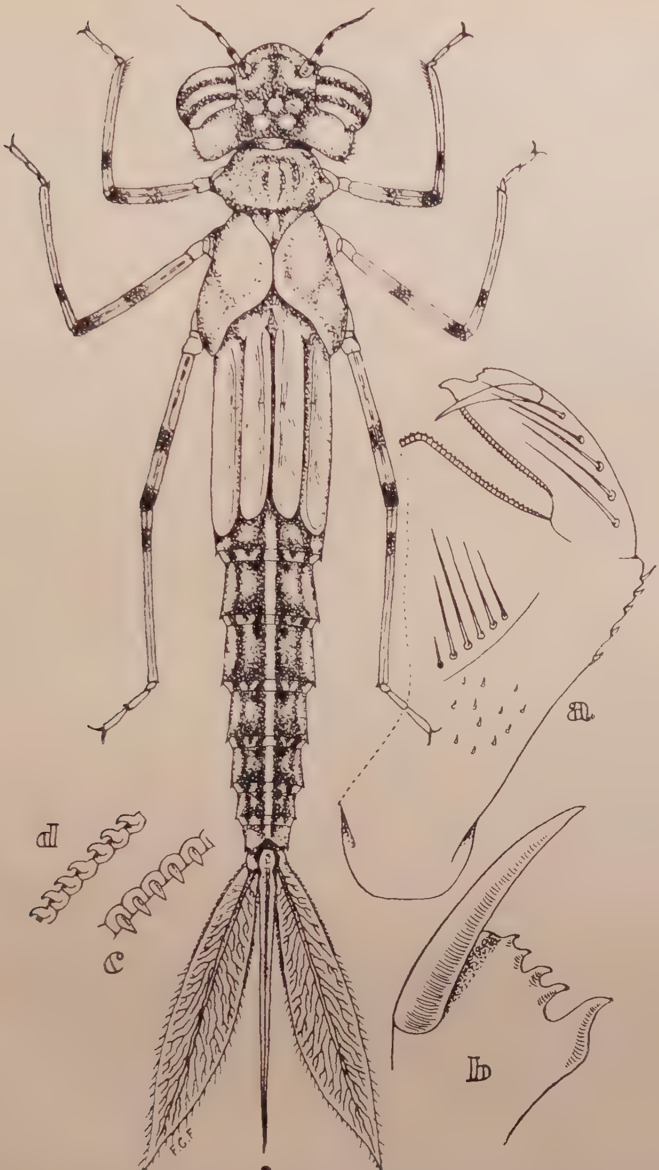

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FIG. 2.—Adult nymph of *I. pumilio*. *a*, Labial mask seen from above; *b*, apex of labial palp or lobe; *c*, bordering teeth of lobes viewed from the front; *d*, the same seen obliquely from the side.

its character from that found in the first instars. The abdomen is cylindrical and bears a narrow pale stripe extending the whole length of the mid-dorsum, flanked on each side by a duplicate dark stripe which broaden and become confluent at the base of each segment save the 10th; the intersegmental membranes are striped and spotted with dark pigment. All segments from 4 to 9 bear a small latero-basal spine. The caudal gills are long, narrow and lanceolate, the apex tapering to a fine point; only a vestigial node is present, which is situated at the junction of the basal and middle thirds of each gill. Laterally, a row of small spines borders each gill from the base to the level of node to the number of about 40 on the outer side and 25 on the inner, and these are succeeded by short hairs to as far as the apex. The lateral basal spines are the only indication of a node, there being no visible sign of such on the surface of the gills. The tracheae are still duplicated down the axis of each gill and from them run numerous oblique ramifying branches. The labial mask is triangular in outline, shallowly cupped in the apical half and with the mentum produced in a slightly obtuse angle (but not minutely notched at apex as Roster stated); the lateral palps end in a robust beak-like hook or tooth preceded by four other smaller slightly curved teeth and these by a robust but moderately short moveable hook (fig. 2, *b*). There are 5 or, more rarely, 6 setae on the middle lobe and 5 on the lateral palps, the former having a field of very small setae posterior to them. Both the middle and lateral lobes are fringed with a row of small, closely-packed teeth, each shaped like a rose-thorn (fig. 2, *c* and *d*). The outer border of the mask anteriorly is furnished with 5 small spines.

BIOLOGICAL NOTES.

In the natural state the nymphs inhabit shallow waters chiefly on peaty moors. They lurk in the weed and scirpus and are thus extremely difficult to dredge; in the aquarium they were found to be extremely active, diving rapidly to the bottom like minnows; when observed but not disturbed they moved round the reed stems to which they clung so as to put it between themselves and the observer. Many specimens lost their caudal gills either by autotomy or by actual attacks from others, but these were replaced by smaller gills at the next ecdysis. Loss of these structures did not appear to affect their respiration so that I am compelled to think that the function of the tracheae in these organs is more for support than for respiratory purposes, just as they are employed to stiffen the main veins of the wings. Without the network of ramifying branches, it is obvious that the flimsy membranes of the gills would collapse and be quite useless for propulsion purposes. Without the gills the nymph is a singularly helpless creature.

The long, narrow, lanceolate caudal gills will serve to determine the genus of this nymph, whilst the number of setae on the middle and lateral lobes are the only sure guide to determine it from the nymph of *Ischnura elegans*, which has 6 on the lateral lobes and 4 to 5 on the middle one, although subject to some variation. In a series of nymphs it will be found that *elegans* has one more seta on the lateral lobes and one less on the middle than *pumilio*. The size of *elegans* given by Lucas is an underestimate and it may be due to his use of spirit specimens and exuviae, both of which show considerable shrinkage due to telescoping of the abdominal segments and distortion of the caudal gills; *elegans* is some 5 mm. longer than *pumilio* when full grown. The nodus in *elegans* is somewhat nearer the apex of the gill than in *pumilio* and is far better defined by the presence of a notch and a nodal line on the surface of the gill.

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THE ZOOGEOGRAPHY OF THE ETHIOPIAN SPECIES OF *PHLEBOTOMUS* AGASSIZ (DIPTERA, PSYCHODIDAE).

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Most records of the distribution of *Phlebotomus* in Africa are referable to the political divisions of the continent. As a rule, however, individual localities are accurately stated and can be identified on a map showing the zoogeographical areas. The present communication is an attempt to summarize the records of distribution of the Ethiopian species of the genus *Phlebotomus* in terms of the zoogeographical areas of the continent.

It has been necessary in compiling this work to discard many of the older records summarized by Sinton (1930), as most of them were made before the importance of internal taxonomic characters, such as the buccal armature, pharynx and spermatheca, was recognized. With such records we have, as a general rule, retained only those in which specific determination could have been accurately made on external characters.

It has to be remembered also that over large areas of Africa the records are scanty because little collecting has been done. It is always possible that intensive study in some of those areas might greatly increase the number of known species and alter the picture considerably. Nevertheless, the sandfly fauna of the Ethiopian Region is remarkably homogeneous compared, for example, with that of the Neotropical Region, where extension of studies to include wild sandflies has recently revealed a rich and varied fauna with many new species. The writers have devoted special attention to the study of wild sandflies (Kirk and Lewis, 1947) in the Sudan and East Africa, and in observations extending over the past ten years have been impressed by the homogeneity of the sandfly fauna of this area.

Since they are important vectors of disease, insects of the genus *Phlebotomus* have been intensively studied during the past twenty years and elaborate schemes of classification have been proposed by various workers. On account of the special conformation of the mouth parts for sucking blood, family rank has been claimed for the PHLEBOTOMINAE, with a view to the creation of several genera. According to Tonnoir (1935) this claim has been completely invalidated by the discovery in India of the genus *Horaielle,* which still retains its mandibles and is also in other respects a link between *Phlebotomus* and the other PSYCHODIDAE. Hence the records of distribution given below are those of one genus only.

FAUNAL DISTRICTS OF AFRICA.

The classical discussion of African zoogeography is that of Chapin (1932), whose conclusions are based on the distribution of birds. Excluding the sea coasts which have their distinctive avifauna and the Malagasy Region, which he treats as entirely separate, Chapin recognizes 17 faunal districts in Africa. Edwards (1941) later found Chapin's zoogeographical areas suitable for discussing the distribution of mosquitoes in Africa. We have, therefore, based this summary of the records of distribution of *Phlebotomus* in Africa on Chapin's faunal areas. A full discussion of Chapin's scheme is outside the scope of the present work, but will be found in Edwards' (1941) book. We employ the scheme to summarize the records of the Ethiopian species of a single genus because its usefulness has already been established in larger and more intensively studied taxonomic groups.

Chapin's 17 zoogeographical districts are named and grouped as shown below :

I. West African Subregion.

A. *Guinean Forest Province.*

1. Upper Guinea Forest District
2. Lower Guinea Forest District.

B. *Guinean Savanna Province.*

3. Upper Guinea Savanna District.
4. Ubangi-Uelle Savanna District.
5. Southern Congo Savanna District.
6. Uganda-Unyoro Savanna District.

II. East and South African Subregion.

C. *Humid Montane Province.*

7. Cameroon Montane District.
8. Eastern Montane District.

D. *Sudanese Province.*

9. Sudanese Arid District.
10. Sudanese Savanna District.

E. *North-East African Province.*

11. Abyssinia Highland District.
12. Somali Arid District.

F. *Eastern and Southern Province.*

13. East African Highland District
14. Rhodesian Highland District.
15. East African Lowland District.
16. South-East Veldt District.
17. South-West Arid District.

Table I shows the species of *Phlebotomus* known to occur in each of Chapin's districts. There is a regrettable absence of satisfactory records from the Cameroon and Eastern Montane Districts (7 and 8) and from the South-West Arid district (17). Although several species are apparently characteristic of their Provinces, the table illustrates the homogeneity of the sandfly fauna of the Ethiopian Region. Certain species, such as *P. africanus* and its varieties, *P. schwetzi*, *P. squamipleuris*, *P. congolensis* and its varieties, *P. signatipennis* and allied forms (*P. dubius*, *P. occidentalis*, *P. cinctus*, etc.) are very widely distributed. *P. schwetzi* and *P. squamipleuris* are remarkably constant in their characters throughout the whole region. *P. africanus*, *P. congolensis* and *P. signatipennis* show the tendency noted by Theodor (1933) to evolve local

TABLE I.

Species.	West African Subregion.						East and South African Subregion.										
	Guinea Forest.		Guinea Savanna.				Montane.		Sudanese.		North East African.		Eastern and Southern.				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
P. adleri	.	.	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.
P. affinis	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
P. a. var. *vorax*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. africanus	+	+	+	+	+	+	.	.	+	+	.	+	.	.	+	.	.
P. a. var. *ater*	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
P. a. var. *longior*	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
P. a. var. *magnus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. a. var. *meridianus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. a. var. *niger*	+	+	+	+	+	.	.	.	.	+	.	.	.	.	.	.	.
P. a. var. *sudanicus*	.	.	.	+	.	+	.	.	+	+	.	.	.	.	+	.	.
P. alexandri	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
P. antennatus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. aretasi	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
**P. babu*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. buxtoni	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.
P. caffraricus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. calcaratus	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
P. cinctus	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
P. clydei	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.
P. collarti	.	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.
P. congolensis	.	.	.	+	+	+	.	.	.	+	+	.	+	+	.	+	.
P. c. var. *distinctus*	.	.	+	+	.	.	.	.	+	+	.	+	+	.	.	.	.
P. c. var. *firmatus*	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
P. cowlandi	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
P. crossarai	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. decipiens	.	+	.	+	+	+	.	.	.	+	.	.	.	.	.	.	.
P. dubius	+	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.
P. dureni	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
P. eremitis	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
P. freetownensis	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. gigas	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
P. guiraudi	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
P. hirtus	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
P. horgani	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
P. hunti	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
P. ingrami	+	.	+	.	.	+	.	.	.	.	.	.	.	+	.	.	.
P. katangensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. kirki	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
P. lesleyae	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
P. lewisi	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
P. longipes	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.
P. martini	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.
P. meilloni	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. m. var. *suberectus*	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
P. mirabilis	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
P. notatus	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
P. occidentalis	.	.	+	.	.	.	.	.	.	?+	.	.	.	.	.	.	.
P. orientalis	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.
P. papatasii	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.
P. p. var. *bergeroti*	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.
P. pastorianus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. renauxi	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. richardi	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. rodhaini	.	.	.	+	+	.	.	.	.	+	.	.	.	.	.	.	.
P. rossi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. roubaudi	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
P. ruttledgei	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
P. schoutedeni	.	+	+	+	.	+	.	.	.	.	.	.	+	.	.	.	.
P. s. var. *pungens*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
P. schwetzi	.	+	+	+	+	.	.	.	+	+	+	+	+	.	+	+	.

* Recorded from Mauritius.

TABLE I—*continued.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
P. sergenti	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
P. s. var. *saevus*	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.
P. serratus	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.
P. signatipennis	+	.	+	+	.	.	.	.	+	+	+	+	.	.	.	.	.
P. simillimus	+	+	+	.	+	.	.	.	.	.	.	.	+	.	.	.	.
P. squamipleuris	+	+	+	+	+	+	.	.	+	+	+	+	.	.	.	+	.
P. s. var. *dreyfussi*	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
P. s. var. *inermis*	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.
P. subtilis	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.
P. thomsoni	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
P. transvaalensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
P. wansoni	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.
P. wurtzi	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
P. yusafi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
P. yvonnae	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.

varieties in different areas. In the case of *P. signatipennis* many of the original varieties (of *P. minutus*) have now been raised to specific rank, but they are, nevertheless, closely related.

P. clydei, which has a wide distribution in the Sudanese Province, is closely allied to *P. meilloni* of the Transvaal. *P. martini* from the Sudanese Savanna and Abyssinian Highland Districts, may be identical with *P. katangensis* from the Rhodesian Highland District.

P. hirtus may prove ultimately to be a Palaearctic species, not an Ethiopian one. This distinctive species is known by one male only from Hoggar. Hoggar is on the southern boundary of the Palaearctic Region in Africa, but its sandfly fauna includes both Palaearctic and Ethiopian species (Parrot and De Jolinière, 1945). *P. papatasii* is a Palaearctic form which occurs in the extreme northern part of the Ethiopian Region, but further south is replaced by *P. papatasii* var. *bergeroti* and *P. roubaudi.*

In its general features the Ethiopian sandfly fauna shows more resemblance to the Oriental than to the Palaearctic, and has little in common with that of the Neotropical Region. Very little is known about the sandflies of the Malagasy Subregion. We have seen no records from Madagascar and only one from the adjacent islands, that of *P. babu*, an Oriental species from Mauritius.

The occurrence of *P. alexandri* at Kapoeta in the Southern Sudan appears to be an interesting example of discontinuous distribution. The name of this species was selected by Sinton (1928) because its recorded distribution was very similar to that of the eastern conquests of Alexander the Great: Greece, Turkestan, Mesopotamia and the North-West Frontier of India. The species occurs also in North Africa, and Parrot and De Jolinière (1945) have found it as far south as Hoggar, which lies near the northern boundary of the Ethiopian Region. Kapoeta, in the Southern Sudan, is far removed from this area of distribution, and *P. alexandri* has not been encountered by the writers in fairly extensive collections made during the past ten years between Kapoeta and the northern boundary of the Ethiopian Region in the Sudan. Kapoeta is topographically like an island of the arid Northern Sudan displaced into the Southern Sudan, and it is of interest to note another record of discontinuous distribution provided by the discovery of the horned viper (*Cerastes cornutus*) in a collection of snakes from Kapoeta (Corkill, 1946).

ECOLOGICAL CLASSIFICATION.

We have drawn attention elsewhere (Kirk and Lewis, 1947) to the gradation in colour seen in Sudan species of *Phlebotomus*, specimens from the northern desert areas being relatively pale, those from the more humid south having much more heavily pigmented chitinous parts. Dark southern sandflies include *P. simillimus*, *P. decipiens*, *P. ingrami*, *P. africanus* var. *niger* and intraspecific dark variations are seen in southern specimens of *P. schwetzi*, *P. congolensis* and its variety *distinctus*.

Specimens from the arid plains tend also to be smaller, more compact and much more hairy than those from higher altitudes and more humid conditions. The contrast between *P. alexandri* in the plains near Kapoeta and *P. sergenti* var. *saevus* in the nearby Imatong hills illustrates this, as does also the difference in appearance between *P. orientalis* from the plains and the related *P. longipes* from the hills. In *P. schwetzi*, *P. signatipennis*, *P. congolensis* and its variety *distinctus* we have noted similar (intraspecific) differences between specimens from the plains and from the hills.

In the Sudan, *P. calcaratus* has always been found in association with rocky and sandy habitats. *P. clydei* is typically an inhabitant of the arid plains. In the Belgian Congo, *P. gigas* and *P. mirabilis* are very large and distinctive cave-dwelling forms with some unusual features, probably associated with adaptation to the spelaean habitat.

ACKNOWLEDGMENTS.

We are grateful to Dr. L. Parrot, of the Institut Pasteur d'Algérie, for much help and information, and to Dr. M. Wanson, of the Service de l'Hygiene, Congo Belge, for the identification of many localities in the Congo.

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LARVAE OF THE BRITISH TRICHOPTERA: 27.

By N. E. Hickin, Ph.D., F.R.E.S.

Halesus digitatus Schranck (Limnophilidae).

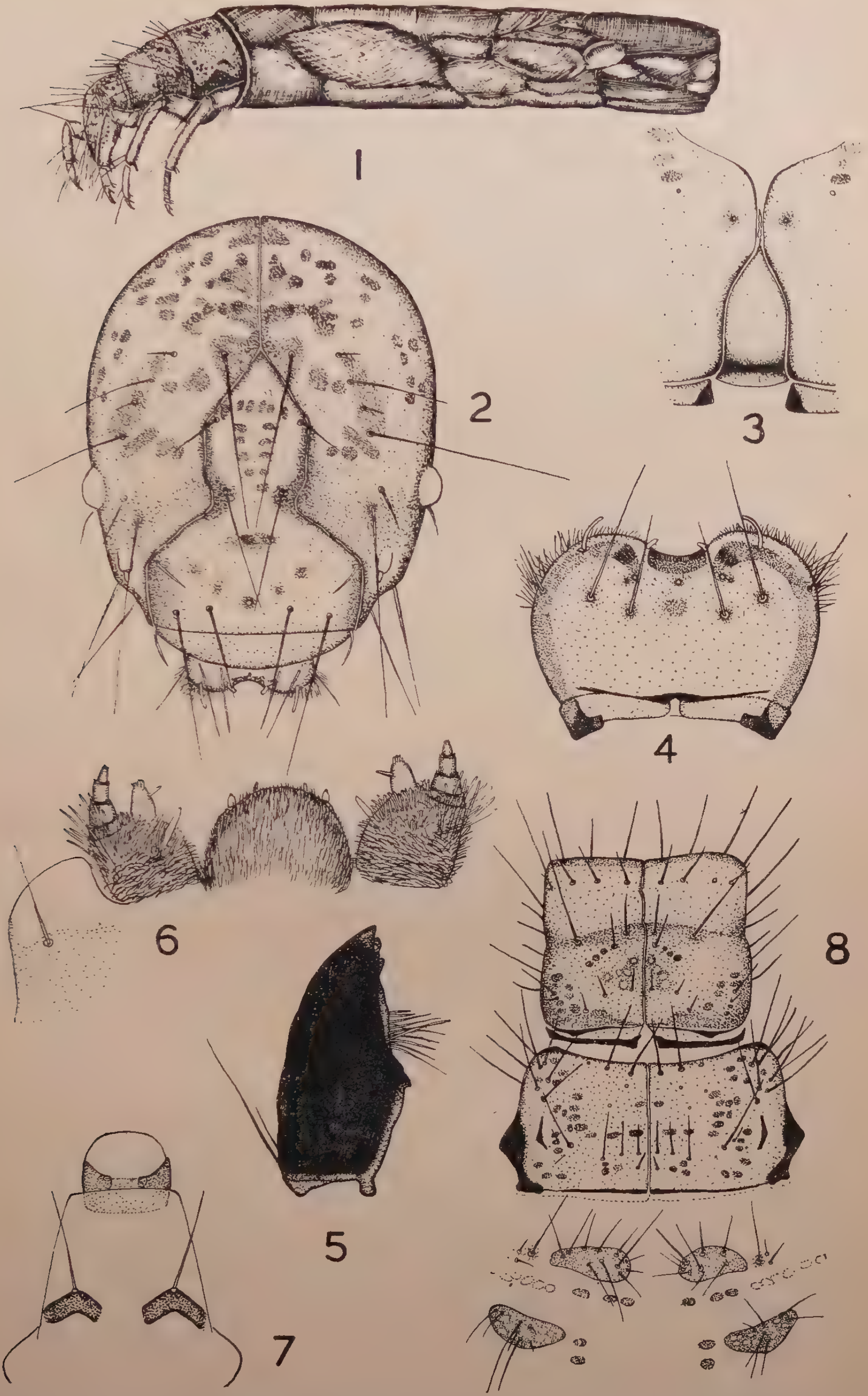
The habitat at Nutfield, Surrey, where larvae of this species were obtained, is described in my description of the larvae of *Chaetopteryx villosa* Fabricius in this series of short papers (1948, *Proc. R. ent. Soc. Lond.* (A) **23**: 59). Twelve larvae were collected on 27th July, 1946, and from them two pupae emerged on 25th October of the same year. As very often happens when rearing Trichoptera under aquarium conditions, the pupae died before emergence of the adults. The pupae swam briskly to the surface of the water and crawled out by means of stalks provided for the purpose, but thereafter did not appear to be able to break the pupal integument. However, by dissection of the pupal integument the imaginal genitalia were made out as those of *Halesus digitatus.*

Examination of this larva was undertaken after heating in 10 per cent. caustic potash solution as the very dark colouration of the fore part of the body otherwise renders examination difficult.

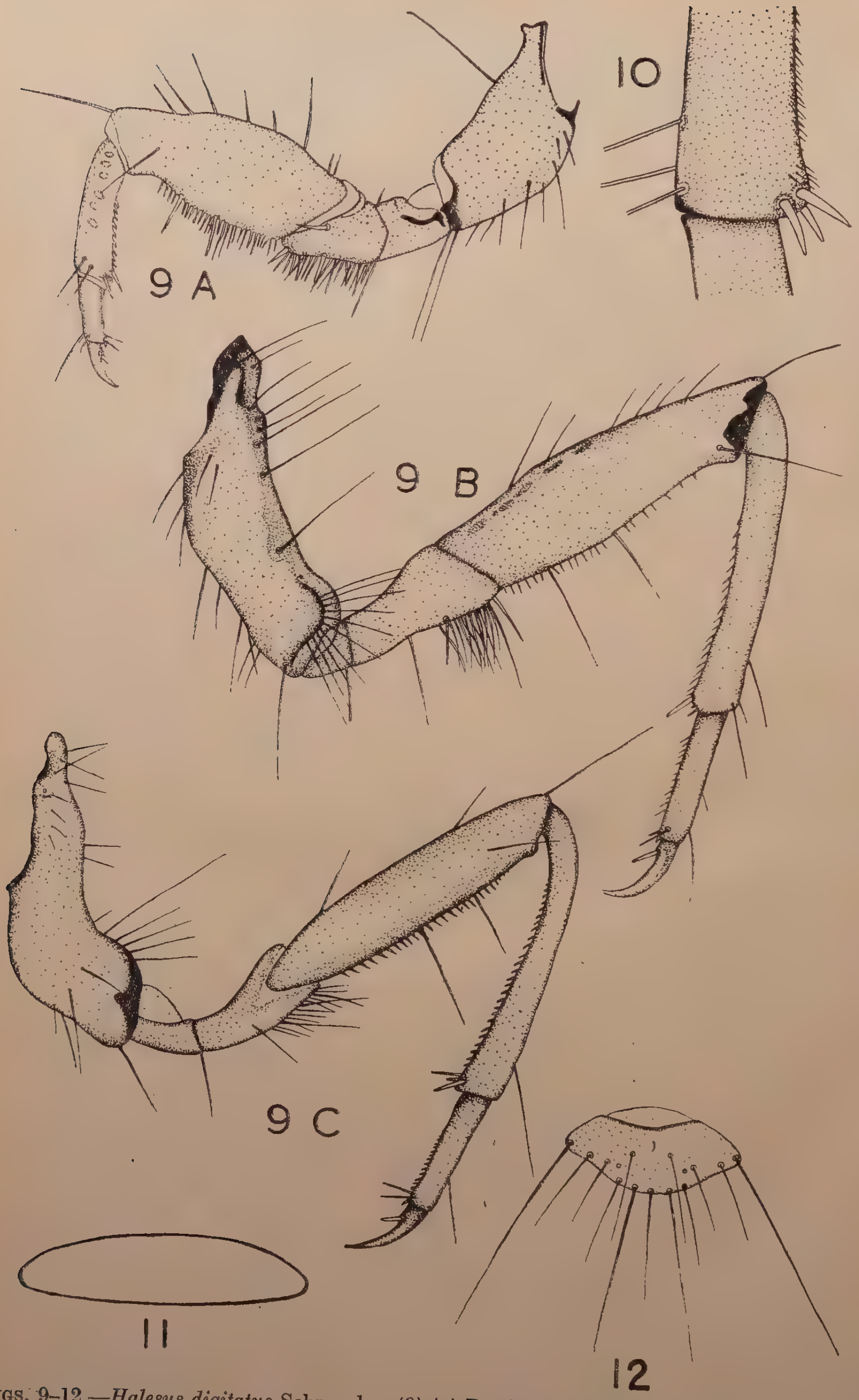
Larva.—Eruciform. Head and thoracic nota almost black in colour, abdomen creamy-white. Length 20 mm., width 4 mm.

Case (fig. 1).—Made of portions of leaves and other vegetable débris, small stones, sand grains, etc. Where the case is composed entirely of leaf portions it resembles the case of *Limnophilus lunatus.* Sometimes a small stick is stuck on to the side of the case when it resembles that of *Anabolia nervosa.* Case tapers slightly posteriorly, and in some specimens very slight curvature is noticed. Length 23–27 mm., width 4·6 mm.

Head (fig. 2).—Orthognathous, dark golden brown with large number of small dark brown marks. Lateral margins of aboral part of clypeus parallel, giving it square appearance, surmounted by the triangular aboral vertex. Antennae small; marks and chaetotaxy as shown in fig. 2. *Gular sclerite* (fig. 3).—Not completely dividing the genae. Where the genae meet, however, remnants of the attenuated vertex of the gular sclerite are seen. *Labrum* (fig. 4).—Deeply notched and sclerotised anterior margin. Lateral margins sclerotised. The median marginal spines (on each side of the excision) short and blunt. The outer anterior spines curved and blunt. The lateral spines moderate in length and sharp. *Mandibles* (fig. 5).—Black, four teeth with some slight asymmetry. Group of light-coloured hairs on inner margin of each mandible. One long and one short black hair at the base on the outer side of each mandible. *Maxillae* (fig. 6).—Palp four-segmented, proximal segment squat. Maxilla hairy, hairs at base of palp long, light in colour and blunt. Large blade-shaped spine present. *Labium* globular and hairy. Labial palp two-segmented, distal segment small, proximal segment large but partly inserted into the labium which, on account of the globular shape of the labium, appears to arise on the ventral surface. *Thorax* (fig. 8).—Prosternal horn present, dark golden brown in colour. Pronotum sclerotised and extending over pleural region, strongly convex mid-dorsally immediately posterior to a transverse furrow. Dark golden brown shading almost to black along margins. Some variation in the pattern of marks and not always symmetrical. Median longitudinal suture present. Mesonotum completely sclerotised



FIGS. 1–8.—*Halesus digitatus* Schranck. (1) Larva in case. (2) Head of larva. (3) Gular sclerite. (4) Labrum. (5) Left mandible from above. (6) Maxillae and labium from above. (7) Labium from beneath. (8) Thoracic nota.



FIGS. 9–12.—*Halesus digitatus* Schranck. (9) (*a*) Prothoracic leg ; (*b*) Mesothoracic leg ; (*c*) Metathoracic leg. (10) Distal end of metathoracic tibia. (11) Sternal plate (third abdominal segment). (12) Anal sclerite.

with median longitudinal suture. Dark golden brown, black in the area of the lateral projections and at the lateral extremities of the anterior margin. In addition to a pattern of dark brown marks, a lunate black mark is present near each lateral projection. Metanotum only partially sclerotised. Anterior pair of dark brown kidney-shaped sclerites are divided from posterior pair by a transverse band of small marks. Posterior sclerites have pattern of light marks as shown in the figure and a pair of small dark marks are situated near the inner extremity of each of the posterior sclerites.

Legs (fig. 9.*a*, *b* and *c*).—Prothoracic legs short, meso- and metathoracic legs about equal in length. On all legs two spines at distal end of tibia and tarsus with small, short, blunt spine directed downwards between each pair in the tarsus, but in the tibia the spine is larger. In meso- and metathoracic legs posterior edge of tibia and tarsus with row of short spines; in prothoracic legs a row of short spines on tibia only.

Abdomen.—First abdominal segment greyish with a number of short stout bristles arising from small sclerotised patches on ventral surface. Protuberances small. Remainder of abdomen creamy-white, cylindrical. Lateral line present on the second to the seventh segments inclusive. The associated groups of sclerotised tubercles are present also in the anterior part of each of segments two to six inclusive. The number of sclerotised points appears to be eight on each side of the segments. Sternal ovoid plates are present on segments two to seven (fig. 12) but one larva examined showed no plate on the second segment. The sternal plates become progressively larger posteriorly and have a thin sclerotised brown margin. Filiform abdominal gills present. Sclerotised tergite present on ninth abdominal segment. Anal claw with additional single auxiliary claw.

Note.—Nielsen has made an important contribution to the published work on the immature stages of this species. Exact head measurements and length and breadth of the larva elicited valuable information concerning the life cycle and the incidence of the five stadia at different collecting times.

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TRACHEAL GILLS IN SOME AFRICAN CULICINE MOSQUITO LARVAE.

By D. J. Lewis, M.A., F.R.E.S.

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Among the larvae of Culicini many species show modifications of the respiratory and other organs in association with particular conditions and habits. In this paper are described organs believed to be tracheal gills, together with modifications of structure and habit suited to a particular mode of life. Before discussing these, however, it is profitable to consider Culicine larvae as a whole and to review some previous work on a particular series of modifications, with special reference to the anal papillae.

Hopkins (1936), when discussing modifications in Culicine larvae, assumed that a typical larva was one that bred in places of the ground-pool type, ingested micro-organisms swept into its mouth by the action of the mouth brushes, and obtained at least the greater part of its oxygen from the atmosphere. He described modifications associated with life in small containers, life in saline waters, respiration from aquatic plants, browsing on the bottom and predacity. Wesenberg-Lund (1920–21) discussed bottom-dwellers which fed by browsing. The larvae observed by the present writer show, in different degrees, a tendency to live largely on the bottom, independent of oxygen from plants, and to use their mouth brushes for sweeping in particles. The following are some previous observations of interest in discussing this mode of life.

With regard to posture, several species have been found to rest inverted on the bottom for considerable periods. For instance, the larvae of at least one species of *Aëdomyia* often support themselves on the dorsum of the thorax and the tip of the siphon (Hopkins, 1936).

With reference to the head, Wesenberg-Lund considered that large multiple antennal tufts might have the function of filtering large particles from the water before it arrived in front of the mouth brushes, and suggested that these brushes, in addition to feeding and sometimes locomotion, had a third function of renovating water near the larva. He also pointed out that, in the small Danish mosquito fauna, the larvae which swept in food particles, together with some other species, had a long dense apical maxillary tuft bordering the space into which the food particles were swept. He also noted the well-developed mouth brushes and the fringe on the mandibles of plankton-eating species.

Mr. P. F. Mattingly has kindly informed me that Mr. J. Muspratt observed, in atypical *Aëdes argenteopunctatus* Theobald and in *Culex argenteopunctatus* Ventr. and *C. weschei* Edwards in Rhodesia, a bladder-like organ beneath the head coupled with a remarkable extension of the tracheal system into these organs and into the anal papillae (Hopkins, 1949). In the larvae of *Aëdomyia* a large retractile organ of unknown function arises near the base of the antenna, according to Hopkins (1936), who also suggested that the large antennae and palps in this genus were used to direct into the mouth the current of water set up by the mouth brushes.

With regard to the thorax, Iyengar and Menon (1948) have shown that the

PROC. R. ENT. SOC. LOND. (A) 24. PTS. 4–6. (JUNE 1949).

larva of *Harpagomyia genurostris* Leicester rests supine on the bottom, supported on the tip of the siphon and on specially modified thoracic hairs, and has gills with well-developed tracheoles.

Concerning the abdomen, Wesenberg-Lund noted an unusual development of hairs on the apical part of the siphon of some bottom-dwellers, which provided them with points of support when resting inverted on the bottom, and mentioned the use of spines on the valves in some species.

The anal papillae of Culicine larvae were for many years known as gills. Da Costa Lima (1914) discussed an American species whose larvae could remain under water for about an hour and had anal papillae with fine tracheal ramifications running backwards and forwards. He considered that, in general, larvae with papillae of this nature stayed longer below water.

Koch (1919) pointed out that certain *Culex* larvae, breeding in foul water, could not obtain much oxygen from the surface, but Wesenberg-Lund remarked that Koch's conclusions were probably inapplicable " with regard to all those larvae which live in natural ponds " and criticized him for taking " the biological and physiological results relating only to *C. pipiens* as a prototype for all mosquito-larvae." Wesenberg-Lund considered that his own work and the drawings of Howard, Dyar and Knab (1912) suggested that in general tracheal gills were more strongly developed in bottom feeders.

Wigglesworth (1933) discussed the function of the anal papillae of the mosquito larva and considered that if their respiratory function was important it should be manifest in the conspicuous papillae of *Aëdes aegypti* L., the species whose physiology he studied. He found that their " respiratory function certainly does not seem very important " and commented : " Were the larvae more dependent on the anal gills for respiration, they might be expected to be better adapted for the purpose, either by the richness of their tracheal supply or by the efficiency of the circulation of blood within them."

The function of the tracheal and blood gills in aquatic insect larvae was discussed by Thorpe (1933). He pointed out that tracheal gills are thin plates or filaments with a copious tracheal supply and only a very small blood cavity, and concluded from the work of himself and others that, although certain types might be very efficient, tracheal gills might be secondary in importance to the general body surface. Referring to Wigglesworth's work on *Aëdes aegypti*, Thorpe remarked on the small tracheal supply and relatively large blood space and, in his paper, classed the anal papillae of mosquito larvae as blood gills. He also wrote : " Since in this species they are much larger than in the majority of allied forms, it is probably safe to assume that in the CULICIDAE as a whole anal gills are of little importance from the point of view of respiration ; a conclusion which is confirmed by my own experiments on *Culex* spp."

Hopkins (1936) was reluctant to regard the respiratory function of the papillae as entirely negligible until a reason could be suggested for their greater development in larvae which bred in tree holes and other places notably deficient in oxygen, and for their partial atrophy in larvae which obtained air from plants.

He remarked that Da Costa Lima had shown that the large sausage-like gills of larvae in small containers had much more complicated tracheal ramifications than the lanceolate type, which is typical of pool breeders. The present writer, however, from his own observations and from reference to Da Costa Lima's paper, does not agree with this generalization.

Wigglesworth (1938) studied the important chloride-absorbing function of the papillae in *Aëdes aegypti* and he, Hopkins (1938) and other workers have discussed this in relation to the size of the large sausage-shaped and other types of papillae.

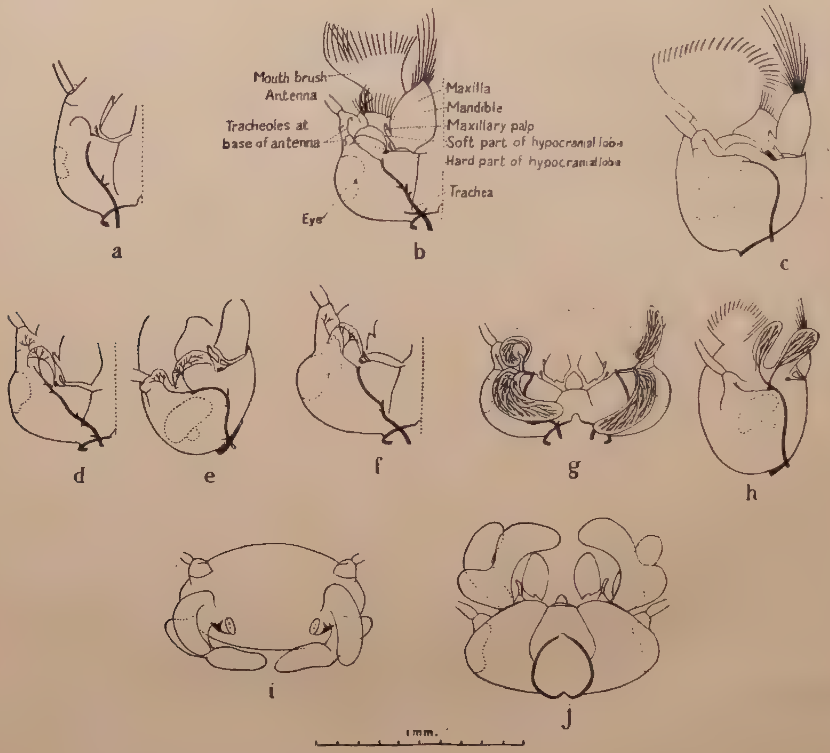
Mouth brush
Antenna
Tracheoles at base of antenna
Eye
Maxilla
Mandible
Maxillary palp
Soft part of hypocranial lobe
Hard part of hypocranial lobe
Trachea
a
b
c
d
e
f
g
h
i
j
1 mm.

FIG. 1.—*a*, The ventro-lateral area of the head of *Aëdes luteocephalus* Newst. (shown for comparison): the tracheoles between the antenna and maxilla in *b* (ventral view) and *c* (lateral view), *Culex decens*; *d* and *e*, *C. sinaiticus*; *f*, *C. argenteopunctatus* ssp. *kingi*: cephalic gills in *g* (ventral view) and *h* (lateral view), *Aëdes argenteopunctatus* from Mvolo; *i* (anterior view) and *j* (posterior view of inverted head), larva, probably of this species, from Juba. In *g* the gills on the right of the figure are displaced to show structure; in *i* and *j* tracheoles are omitted.

In general, a perusal of the literature reveals several structural modifications to be borne in mind when considering bottom-dwelling larvae, and suggests that the anal papillae of Culicine larvae are not to be regarded as gills.

OBSERVATIONS ON SOME CULICINE LARVAE.

In examining some larvae in the Sudan particular attention was paid to the anal papillae and to a region of the head where tracheoles are conspicuous near the surface in some species and which appears to be well suited for use as a respiratory surface. It is on the ventro-lateral area between the bases of the antenna and the maxilla. Water driven backward by the mouth brushes is obstructed by the broad maxillae (figs. 1 *b*, *c*, *h*; 2, *f*) and partly deflected so that a strong current passes over the surface in question. The area comprises the ventral surface of the peduncle of the antenna and the region of the hypocranial lobe (fig. 1, *b*; and Howard, Dyar and Knab (1912)). Tracheoles were drawn shortly after the larvae had been killed with weak formaldehyde and mounted in water.

With regard to posture, *Aëdes argenteopunctatus*, *Culex poicilipes* Theo. and *C. sinaiticus* Kirkp. have been observed to remain for some time inverted on the bottom of containers, a position in which they can continue to feed on plankton.

Superficial tracheoles of the antennal peduncle are well developed in *Aëdes argenteopunctatus*, *C. poicilipes*, *C. decens* Theo., *C. perfuscus* Edw., *C. sinaiticus* and *C. argenteopunctatus* ssp. *kingi* Theo.

Tracheoles are conspicuous in the hypocranial lobe area in *C. sinaiticus*, *C. a.* ssp. *kingi* and *A. argenteopunctatus.* In larvae of the latter from Mvolo and a larva, possibly of this species, from Juba, both in the Southern Sudan, the tracheoles are very numerous and are situated in two pairs of large, thin-walled, curved and slightly flattened papillae which extend outward from the head. The posterior papillae are the larger. These structures, apparently not retractile in life, immediately collapsed when the larvae were cut in half, but could be restored to their normal shape by pressure on the thorax. In the Juba larvae the papillae were very large and the posterior ones indented, so that the anterior pair fitted over them (fig. 1, *i*, *j*). This arrangement produced a superficial appearance of three papillae on each side of the head.

All the above-mentioned tracheoles arise from well developed tracheae arising from the main tracheal trunk of the head, as shown in the figures.

Several of the species examined showed a forward curvature of the siphon, slight in *C. sinaiticus* and *C. a. kingi* and pronounced in *A. argenteopunctatus* and *C. poicilipes.* This appears to reduce the risk of damage to the tip of the siphon when the larva is inverted. In *A. argenteopunctatus* from Mvolo (and possibly elsewhere) the siphon is short anteriorly, so that there is a considerable area of thin flexible cuticle at its base which may facilitate the forward inclination of the organ. The large subventral tufts support the siphon so that its tip does not normally touch the bottom (fig. 2, *f*). Long tufts are also found in *C. poicilipes* and *C. a. kingi.*

In several species the trachea of the siphon is very narrow; in *A. argenteopunctatus* even narrower at its base than the trachea which passes to the anal segment and supplies the papillae. The narrowing may indicate a reduction in the use of the siphon.

The tracheoles of the anal papillae are moderately developed in *C. poicilipes*, *C. decens* and *C. perfuscus*, numerous in *C. sinaiticus* and *C. a. kingi*, and very numerous in *A. argenteopunctatus*, which has much elongated papillae. *Uranotaenia fusca* Theo. has long papillae with numerous tracheoles, but the tracheoles of the head have not yet been examined owing to the opacity of the chitin. In *A. argenteopunctatus* the anal papillae are held in the current of water created by the mouth brushes (fig. 2, *f*) and are so long and richly supplied with tracheoles that in this species at least they appear on morphological grounds to be gills.

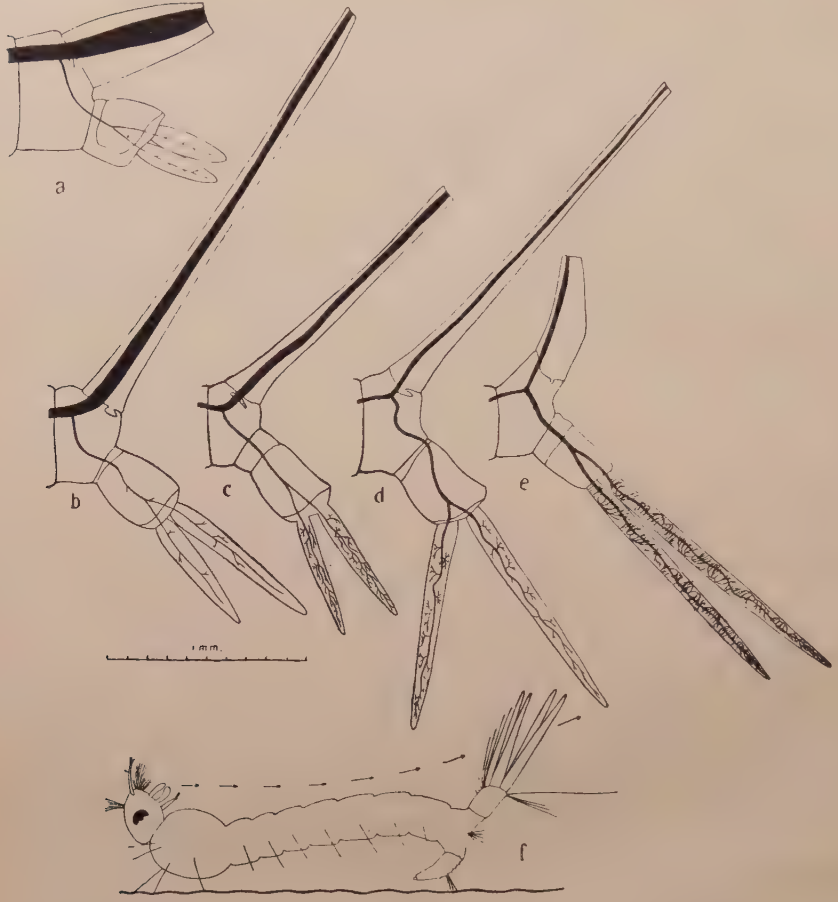

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Fig. 2.—The trachea of the siphon and tracheoles of the anal papillae in *a*, *Aëdes luteocephalus* (shown for comparison); *b*, *Culex decens*; *c*, *C. sinaiticus*; *d*, *C. argenteopunctatus* ssp. *kingi*; *e*, *Aëdes argenteopunctatus* from Mvolo; *f*, a larva of the latter inverted, arrows showing the path of the main current from the mouth brushes.

Well developed tracheoles of the anal papillae occur in several species in addition to the few mentioned above.

Discussion.

Plankton-eating Bottom-dwellers Independent of Plants for Respiration.

A number of species tend to live more or less in this manner, and ways in which they are adapted to it are mentioned in the introduction and the above descriptions. The principal modifications are evidently a partial replacement of aerial by subaquatic respiration by means of the anal papillae and other surfaces, and the adoption of the inverted position.

In at least one species, the larva from Juba, surface tracheoles were numerous in several parts of the body. In such cases the tracheal gills may perhaps be regarded not only as special respiratory organs, but as part of a whole system of surfaces well supplied with tracheoles.

The value of this way of living may be that the larvae are less vulnerable to certain predators the less they swim and that in some breeding places they may find food more easily near the bottom and not have to waste time in swimming up for air.

There is a remarkable resemblance between certain species of two different genera which have adopted much the same habits. Larvae of *Aëdes argenteopunctatus* and species of *Aëdomyia* remain for many minutes inverted on the bottom, and possess thin-walled papillae beneath the head, a curved siphon with very narrow trachea and large tufts. They differ notably in that the whole tracheal system is rudimentary in *Aëdomyia*. It is interesting to recall Hopkins' above-mentioned suggestion regarding the water current in the mouth region of *Aëdomyia* in connection with the evident importance of the current in *Aëdes argenteopunctatus* and some other larvae.

Anal Gills in Culicine Larvae.

In the past, discussion about the possible respiratory function of the anal papillae has tended to centre round the rather small European mosquito fauna and particularly a few species, including *Aëdes aegypti*, in which the tracheoles of the papillae are few. Little evidence of an important respiratory function has been found.

Comparative morphological and experimental studies of the papillae of Culicine larvae in general have not been made because these organs are distorted in most specimens preserved for taxonomic purpose and because comparatively few species occur near laboratories.

From observations on the structure of some African larvae it appears that the papillae of some species act as tracheal gills although they may perform other functions as well.

To ascertain if many species are thus equipped it is desirable to make camera lucida drawings of many larvae in the field. In such work it has been found convenient to place larvae in four groups according to the presence of conspicuous tracheoles near the surface between the maxilla and antenna: (1) with none, (2) with these tracheoles on the peduncle of the antenna, (3) with the tracheoles on the peduncle and in the hypocranial lobe area, and (4) like group three, but with large cephalic tracheal gills.

Taxonomic Significance of the Tracheoles and Cephalic Gills.

In certain localities some species can be identified by means of the ventrolateral cephalic and other tracheoles, but these and the tracheal gills are of little practical taxonomic value because they are distorted or obscured by the usual methods of mounting.

It is well known that the anal papillae of many species vary in size so it is not unlikely that the cephalic gills of *Aëdes argenteopunctatus* may do so. No variation was observed in the Mvolo larvae, but they all came from one breeding place. When Hopkins (1936) figured the larvae of this species he explained that there was some doubt of its identity. If the cephalic gills are of any taxonomic significance their shapes indicate the existence of four forms of the larva.

Those from Mvolo differ from that described by Hopkins in having very long unequal anal papillae, but the males bred from the same breeding place are typical.

The larva from Juba died and no adult was obtained. In addition to the very large cephalic gills it had one or two conspicuous denticles on the basal teeth of the pecten.

There may be two other forms in Rhodesia, since Muspratt's observations suggest that some larvae had no head gills and that others had a rather small one on each side.

SUMMARY.

Some previous work on modifications of the anal papillae and certain other organs of Culicine larvae is summarized. Several authors considered that the repiratory function of the papillae was of little importance.

Types of anal papillae and other structures in some African species are described, including large papillae on the head of *Aëdes argenteopunctatus*. The cephalic and anal papillae of this species are richly supplied with tracheoles.

It is considered that the larvae observed show, in various degrees, adaptations to living on the bottom, independent of water plants for respiration, in an inverted position in which the mouth brushes can sweep in particles. There is a tendency for respiration to be carried out more through surface tracheoles and less through the siphon.

Regarding the anal papillae of Culicine larvae in general, it is concluded that they should be regarded as tracheal gills in some species.

The taxonomic significance of the papillae and certain tracheoles is discussed.

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PUBLICATIONS

The Publications of the Royal Entomological Society are *Transactions* and *Proceedings.*

The *Transactions* form an annual volume, each paper in the volume being issued as a separate part. The parts are issued irregularly throughout the year.

The *Proceedings* are issued in three series :

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Series B. Taxonomy
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The following information is supplied for the guidance of authors wishing to submit papers for publication in any of the Society's journals.

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A uniform method is adopted for the citation of bibliographical references in the Society's publication as follows :

Smith, A., 1936, New Species of COCCIDAE. *Proc. R. ent. Soc. Lond.* (B) **6** : 301-306, pl. 1.

——, 1936, New species of COCCIDAE. *Trans. R. ent. Soc. Lond.* **84** : 901-936.

Titles of periodicals cited are to be abbreviated in the manner indicated in the *World List of Scientific Periodicals, 2nd edition*, 1934.

Authors are entitled to receive 25 copies of their papers free of charge and may purchase additional copies provided that request be made before publication.

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Papers offered for publication in the *Transactions* are considered by the Publication Committee of the Society, which meets usually in the months of May and November. In order that papers may be considered at these meetings it is necessary for the manuscript and drawings for illustrations to be in the hands of the Hon. Secretary fourteen days before the meeting of the Committee.

Papers of less than eight printed pages (approximately 7,000 words) will not normally be accepted for the *Transactions*, and papers by authors who are not Fellows of the Society must be communicated by a Fellow.

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MEETINGS

TO BE HELD IN THE SOCIETY'S ROOMS

41, Queen's Gate, S.W. 7

1949

Wednesday, July 6
,, September 7
,, October 5
,, November 2

THE ROYAL ENTOMOLOGICAL SOCIETY OF LONDON

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